The Squinch Vaults in Joseph Ribes' *Llibre De Trasas De Viax Y Muntea*

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Joseph Ribes' life remains almost a complete mystery, even today. He was a stone mason who worked in 18th century Catalunya, whose *Llibre de trasas de viax y muntea*, published in 1708, testifies to the knowledge and practice of stereotomy in the Catalunya of the 17th and 18th centuries. A first analysis of the content of this manuscript has been introduced in ongoing research that has flagged up its importance in the history of construction (Tellia 2011). This treatise on stereotomy represents the missing link between the knowledge of the skilled stonemasons of the Gothic tradition of the Valencian and Catalan lands, and the consolidated and productive stereotomic traditions found in the Languedoc and the Balearic Islands, a rich blend of reinterpretations of previous treatises of Spanish and French heritage, with the addition of several original solutions.

Probably, of all the families of stereotomic structures described in Ribes' *Llibre de trasas*,[1] the squinch arch is not the element that most characterizes Ribes' treatise while glancing through its pages. In fact he develops only a few examples of "trompes"[2] whose general characteristics are in line with the other major treatises of the time, but a more careful analysis reveals how he introduces a unique feature that stands out and has not been repeated in other essays since then.

The analysis of a few examples of trompes built in Catalunya allows us to open up a new discussion regarding stereotomy's spread in this part of the world and allows us to record the range of geometric and constructive characteristics of the trompes of this geographical area as well as those in culturally-related regions. The similarities in ideas and nomenclature seem to confirm the influence of French and Spanish stereotomy in Catalunya, but we can also foresee a parallel development of certain features whilst the intricate series of relations between cities and stone masons still needs to be completely unveiled and organized in one comprehensive storyboard that records the transition of the skills and treatises covering stereotomy between the Languedoc, Balearic Islands, Valencia and Catalunya.[3]

The squinch vault

This architectural element, the conic vault, allows the transition from a square plan to an octagonal geometry, making possible, for example, the passage between the squared crossing of a church and the octagonal or circular base of a dome that needs to be installed onto it. The Romans developed the use of some typologies of trompes, borrowing them from their oriental provinces, although they did not use this structural node systematically since they were covering squared spaces with cloistered vaults and circular spaces with hemispheric domes. The origin of the trompes as a means of transmission of forces is found in Sassanid Persia from the seventh century, when conic vaults of incoherent stonework were built to support the domes.

The Armenians continued this tradition through the eighth century building squinch vaults in stone ashlars and eventually this heritage reached the Central European Romanic, probably through the contacts occurred with the Crusades. To solve the transition between a square plan and a circular dome, the Byzantines adopted and developed in its full splendour the *pendentif*, the spherical triangles that connect the top of the pillars to the base of the dome. We can record the spread of squinch arches in Catalunya since the 11th century. Initially they were formed by concentric rings of stone, each of them superimposed on the previous one but independent from one another. From the 12th century they were formed of a single conic surface, corresponding to the intrados, made of large and regular cut stones called ashlars, which is when one can begin to notice their stereotomic character.

Gothic grammar used mainly ribs and tiercerons to solve the transition between squared and polygonal forms though trompes were still used in a few cases. In the prolonged construction of Romanic Cathedrals that was ongoing throughout this period, massive squinch arches were built to bear the structural loads and resolve the geometry, such as the beautiful trompes of the Catedral de la Seu Vella in Lleida. The Baroque, rediscovering different geometries and spatial compositions, found a new purpose and meaning for the use of trompes, as is attested to in the treatises and architecture of the time. The major geometrical contribution of the trompes is in the development of conic surfaces onto the plane. These geometrical constructions are also strictly related to the sloping barrel vaults for the determination of the angle within the intrados and vertical faces, and to cylindrical arches for the precise definition of curves in the space.

This paper will not study the niches and the spherical trompes since it is only analyzing squinch vaults with conical intrados. Ribes includes spherical niches in his *Llibre de trasas* in the same folios where he describes vaults. The development of conic surfaces is not finalized with the study of the trompes, in fact it serves as a starting point for the development of templates for spherical vaults. In his manuscript, spherical geometries are solved only with the use of conic developments, omitting the method using meridian developments that is outlined in other treatises.

Squinch vault in the treatise of Joseph Ribes

Ribes describes eight examples of squinch arch, all executed as conical vaults and fully reproducing

Fig. 1: Characteristic saw-tooth geometry in the doorway of the Palau de la Generalitat in Barcelona.

the data needed for its construction: the developed templates of the intrados, developed elevations, sections, the angles of the coursing joints and between faces. Some tracings are characterized by the original "trompillon,"[4] shaped like a saw-tooth, of probable Catalan Gothic origin. In all the other cases he marks a simpler option.

Ribes uses a general solution to describe all of his examples with one exception where he adopts a simpler procedure, that seeks, as we will see hereafter, to mask by tracing unnecessary lines that simulate the more complex geometrical operations that he has used for all the other tracings. This communication compares his tracings with the models of trompes described in the French treatises of De L'Orme (1567), Jousse (1642)[5] and Derand (1643) circulating in 18th century Barcelona and whose date of publication precedes the likely date for the composition of the *Llibre de trasas*, but we cannot be sure that Joseph Ribes would have been able to consult them. In fact we do not know if they arrived before the time he was composing his treatise. We also consider important a comparison with Vandelvira's treatise, as represents the quintessential in the Spanish tradition and gathers examples known to Spanish stonemasons in the 16th century, and a comparison with Gelabert's manuscript brings up evidence of the general knowledge of the Balearic stonemasons which is especially important for its geographical proximity.

Other Spanish treatises contemporary to Vandelvira do not include trompes (Martinez de Aranda, Rodrigo Gil de Hontañon) but this does not necessarily mean that these solutions were unknown to the stone masons in their area and Derand's words should be recalled, stating that the solutions presented in his work were not original and that he gathered and collected a series of practical and empirical procedures that were scattered among the corporations and kept carefully secret. Surprisingly, we cannot find any particular similarities with Gelabert's manuscript in the nomenclature of the trompes as has been recorded for the other families of stereotomic elements in his treatise.

Patxina ab canto – Squinch Vault on squared corner (Folio 217-218, 230, 233-234)

Ribes describes 4 variations of this type of trompe. The first example of trompe (Ribes and Folio 217-218) remains unnamed by Ribes but is probably the most distinctive and original trompe design in his treatise and certainly not the simplest to solve. The unique feature of this trompe is the "trompillon" with its saw-tooth geometry. Different reasons may have determined the form of this original stone cut, seeming to follow the intention of interlocking the blocks, thus balancing the horizontal dispersion of forces resulting from asymmetrical thrusts. Its shape eases the construction as it precisely accommodates each voussoir in its position, satisfying an aesthetic demand with the unusual design of the resulting joint lines and its plastic volume.

It is possible to identify this characteristic feature in structures located in Barcelona and in its surroundings that could either have been sources of inspiration or direct applications of the principles described in the manuscript.[6] Built with the same constructive logic, we can see voussoires shaped as segmented volumes laying on the spring line of the main doorway of the Palau de la Generalitat in Barcelona built by Pere Blai in 1596 (Fig. 1). Symmetrically positioned on the two sides of the arch, these blocks are receiving the voussoirs and the forces acting on the doorway. Other vaguely similar designs of this original stone cut can be found in the treatise of J. Chéreau (1575), in

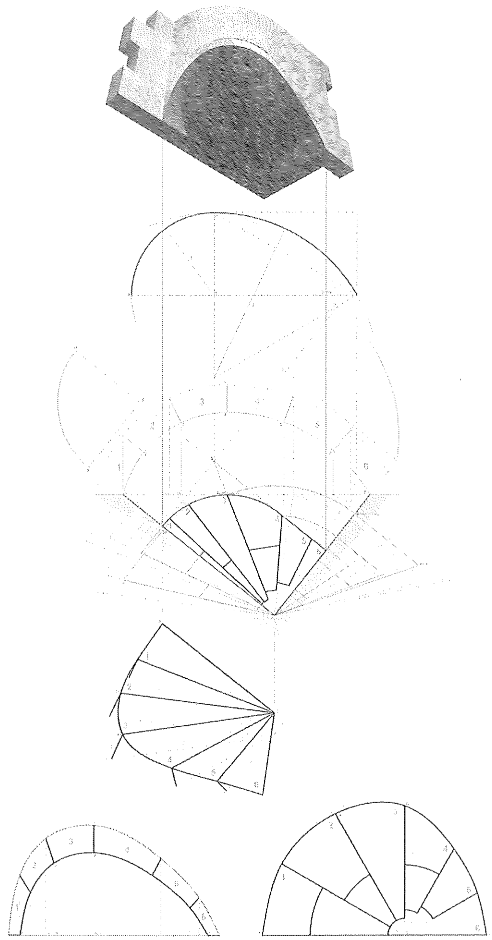

Fig. 2: Tracing of the Hospital de la Santa Creu 15th century; drawing by Tellia.

the trompes of the Hôtel de Lamoignon in Paris (1584) (Fig. 3), in two trompes of the 17th century in Rue Basse St. Pierre in Saumur, and in a trompe in Toulouse not clearly dated, though these examples are more closely related to the trompe that Ribes traces in Folio 243.

In the trompe in Folio 217-218, the plan and section are complemented with the true elevation, the development of the intrados and the dimension of the angle that each block forms with the horizontal plane. Ribes draws the true dimension of the face joints as a parallel line, showing the thickness of the ideal shell, in contrast with Jousse and Derand,

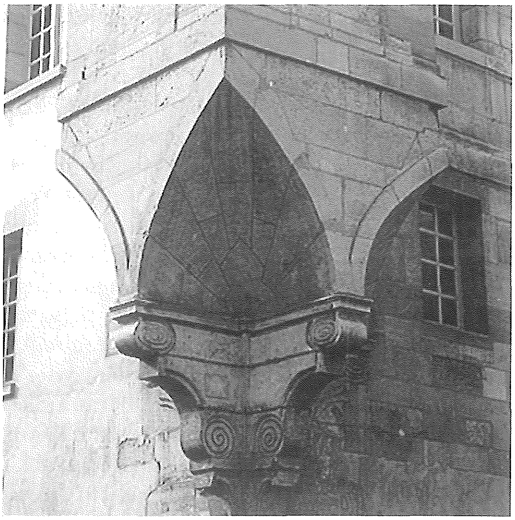

Fig. 3: Trompes of the Hôtel de Lamoignon in Paris (1584).

whose tracings show the voussoirs of the extrados pointing to the vertex of the intrados, resulting in a shell with a thickness that decreases towards the vertex of the cone. De L'Orme, probably to avoid confusion and overlapping lines, restricts himself to marking the dimension of the vertical face and only the initial thickness of the trompe next to it.

Tracing the joint faces with constant width results in the constantly varying thickness of the vault and in the elevations of the voussoirs' faces. Ribes has produced an offset of the joint lines to determine the dimension of the face joints. Through a simple geometrical construction this diagram also provides the dimension of the angle between the intrados's edge and the vertical face of the block that will be used to build the "*saltarregla*."[7] Moreover, Ribes marks on the true dimension of the face joints, the fragmentation of each voussoir and the point of insertion of the adjacent voussoir. This model of trompe is not described in Gelabert's treatise. He may have considered it a simplification of the *Pechina de medio punto en tres paños*, the polygonal-shaped trompe whose templates are found with the same methodology. Vandelvira describes this example, but with an important difference; in his treatise the height of the trompe is determined by the orthogonal projection of the guide arch on the plan that is normal to the bisector angle of the trompe [the guide arch represents the elevation], while in Ribes' drawing the height of the trompe is established by the conical projection of the guide arch [the guide arch represents the section], this resulting in a much higher trompe. For this type of trompe, Jousse draws a segmental arch to avoid excessive height of the vault while Derand uses the same section as Ribes.

The whole methodology in Ribes' treatise is oriented toward one goal: to precisely define the

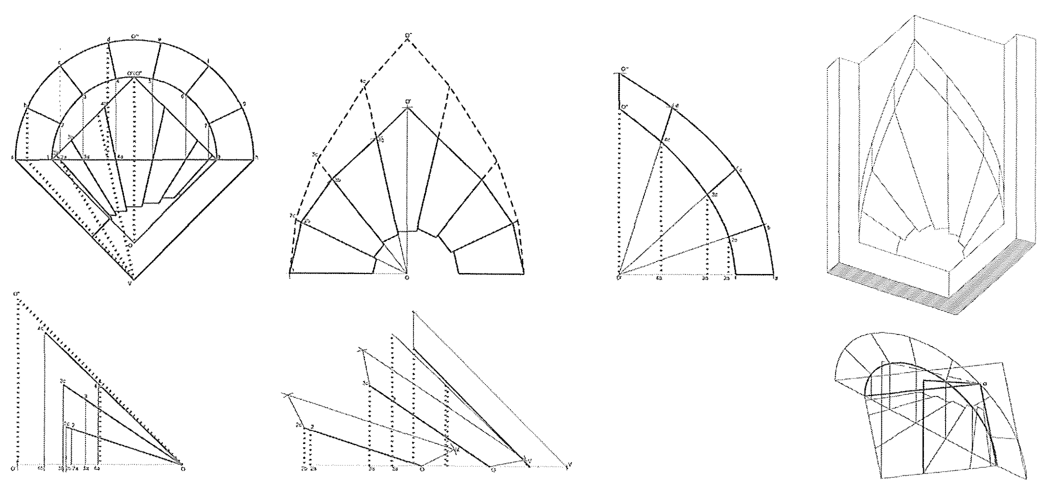

Fig. 4: Tracings of the *Patxina ab canto* (Ribes and Folio 217-218); drawing by Tellia.

panels that wrap around each voussoir. Exactly as De L'Orme, whose treatise seems to follow strictly the guidelines, Ribes works with similar triangles belonging to the vertical section that have been rotated and overturned on the horizontal plane and subsequently builds the templates through trilateration. If a triangle that is lying on a constructive section defined by the architect is known, it is therefore possible to find a similar rectangle laying on the same plane of the previous triangle. If we know one dimension of the second triangle, this implies that the similar triangle will be defined in all its dimensions. The same operations are repeated to define the points of the extrados needed to build the face joints templates. In his manuscript, Ribes inform us with all the necessary data to shape the voussoirs: the plan and section, the slope that the voussoirs forms with the horizontal plane, the template of the development of intrados, the template of the elevation.

Vandelvira, with an equivalent graphic process and almost identical concept, utilizes similar triangles and overturning for building the diagrams that he uses to find the true dimensions of the stone blocks. Ribes produces a notable error in his drawing probably caused by inattention or by having to make it fit on the paper. The length of the developed voussoirs of the intrados does not correspond to the dimension that he should have traced. In fact he draws each joint using the planar length, while he should have used the real length of the joint that can be found in the construction diagram on the same folio. Considering for example the first voussoir, instead of using the true dimension O-2c taken on the development diagram, he uses the projected length O-2b (Fig 4, the dashed lines represent the ideal developed templates of the intrados built with the true dimensions).

Other inaccuracies in the tracing can be found in the side elevation of the trompe that also represent the templates of the vertical faces of the stone blocks, whose edge has not been drawn correctly, probably because Ribes used only a compass and a ruler.

The tracings of Folio 230 and Folio 233-234 do not present the segmented "trompillon" but a more common solution. The symmetry of the system allows us to require just half of the templates in order to build the whole. The graphics to calculate the slope and the true dimension of ashlar stone of the conic vault is very similar to the characteristic trait of De L'Horme, to Jousse's representations and to one example used by Derand. The tracing process is geometrically correct and does not present the mistakes noticed in the first trompe.

Fig. 5: Trompes in the clock room of Tarragona Cathedral bell tower.

Patxina dela primera planta – Trumpet Squinch Vault (Folio 229, 241-242)

The description of trompes in Ribes' treatise proceeds with inconstancies in the presentation as he does not illustrate similar trompes consecutively, nor does he group them for their difficulty of execution. This model of trompe (Folio 229) is the simplest squinch arch, it is found in many Romanic churches in Catalunya as well as in several churches in Mallorca. One should also recall the imposing examples built in the clock room of the bell tower of the Tarragona Cathedral (Fig. 5), which are similar to the ones in Mallorca for their dimensions and geometry.[8] The geometrical construction follows the pattern described in the other treatises for this case. After dividing the intrados into equal voussoirs, the data needed to construct this trompe consists in the template of the interior face of one voussoir, the angle that this stone block forms with the vertical wall and the template of the head of the stone, that is to say, the panel of the face of the stone that remains in a vertical position.

At variance with the drawings made by Vandelvira and Gelabert for this kind of trompe, Ribes completes the tracing with the construction and projection lines of each stone ashlar of both the intrados and the extrados in the plan and in the section, possibly trying to show that he has used the same method adopted for other trompes. In this case the construction method that calculates the true length of the voussoir can still be used, but is not necessary. Ribes knows it, and solves it with the method described by all the other treatises as it is possible to see from the compass marks left on the original manuscript. It is interesting to note another imperfection in Ribes' drawing in that he has added the lines that represent the bearing walls and, probably by mistake, does not match the thickness of the vault, as he has done with the other examples.

The Trumpet Squinch Arch of Folio 241-242 presents another variation of the segmented "trompillon." This asymmetrical design, instead of being a unique stone, is made up of several smaller wedges of stone, one for each voussoir making up the conic vault. So, though equal in geometrical concretion to the other squared squinch arch in Folio 229, Ribes provides us with more information regarding the segmentation of the voussoirs. We can observe an incongruence in the thickness of the section cutting the cone next to the vertex.

Patxina apañada – Polygonal Squinch Vault (Folio 231)

The main feature of this trompe is its segmented edge, consequence of constructions with polygonally shaped corners, that results in an intrados surface awkwardly cut. The process used for tracing templates in Ribes manuscript is the same that is used for the other trompes and doesn't present any particular technical difficulty. To facilitate the cut of the stone blocks is important to project the trompe carefully, since voussoires that have joints cutting through the discontinuous edges and through the different vertical planes are more difficult to shape. De L'Orme, Jousse and Derand propose several variations and particular cases of this kind of trompe; Gelabert shows a simpler design very similar to the one described by Ribes. Vandelvira does not describe this typology, indeed it seems to be more common in the Gothic and French tradition. Apart from the already-documented example in Valencia (Rabasa 2011, 299) we would like to recall the trompe of notable dimensions in Felanitx (Fig. 6) and another example, now destroyed, in Barcelona, recorded by Antonio Rovira y Rabassa.[9]

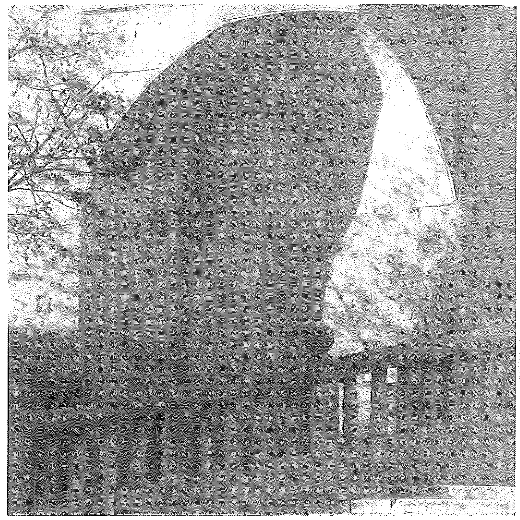

Fig. 6: *Patxina apañada* in Felanitx.

Patxina ab torra rrodona – Cylindrical Squinch Vault (Folio 232)

This trompe is adapted to support a curved wall and presents a seamless rounded edge resulting from the intersection of the conical vault with the cylinder of the vertical enclosure. The geometry developed by Ribes for *Patxina ab torra rrodona* corresponds to the model that Vandelvira calls *Trompa de Montpellier*. In both authors the geometry of the edge is determined by the conical projection of the guide arch, attribute that produces a higher vault. The model that Vandelvira calls *Pechina torre redonda* has a different geometrical feature because the guide arch is projected orthogonally to the façade. Jousse and Derand will use the same differentiation and nomenclature; Gelabert describes this model with a certain confusion (Rabasa 2011, 302) but the geometry of the developed intrados seems to make him stand in line with the other tracists. De L'Orme doesn't draw this model in its treatise but in 1536 builds two trompes of this kind in Lyon.

For the geometry of this trompe, it is especially important to unfold the three-dimensional curve of the curved edge onto a plane with as much accuracy as possible so that its length is preserved. This is an important stage in establishing the face templates and Ribes introduces a mid-point construction for each voussoir for more precision. Also in this case, the main technical difficulty is found in its execution, mainly in the rounding of the tops of the ashlars.

Patxina ab canto [escasana] – Squinch Vault on squared corner [segmental arch] (Folio 243-244)

Ribes concludes his treatise with another squinch vault that he again calls *Patxina ab canto* (Fig. 7). This model differs from the tracing previously described in Folio 217-218, for its section, made up of a segmental arch, and for the device he uses to construct the "trompillon," composed of various small stone wedges. This layout is similar to the trompes previously cited in Paris (Fig. 3), Toulouse and Saumur. The construction method is the same as that shown in example of Folio 217.

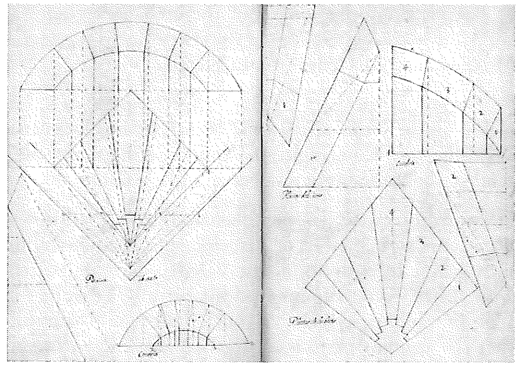

Fig. 7: *Patxina ab canto* (Ribes and Folio 243-244).

In Catalunya, we record a persistence of stereotomic or proto-stereotomic elements that arose with the Romanic squinch vaults and matured through the Gothic Age until reaching their technical splendour in the late 18th century. In all probability the most original and purely Catalan examples, even if not the most virtuous, can be found up until the early 18th century, just before the arrival of Bourbon reign and the institution of the Academies. With a few distinguished exceptions, the stereotomists of the 17th century were expected to supply templates but not designs (Sanabria 1989, 299) and Ribes seems to embody this profile in his effort to produce buildable examples. The overall simplicity of his drawings, the attention to particular details such as the angles, the dimension and proportions of the voussoirs lead us to believe that his work was not a showy treatise but a catalogue of concrete examples. The *Llibre de trasas* seems to share the technical character of Vandelvira's treatise, written for the specialized use of master masons, and to have been influenced by De L'Orme's definition of methodology and ideas of tracings. The novelty and originality of his details bring a notable contribution to the history of Catalan stereotomy and a small number of them have been documented in this study.

Notes

1. The treatise doesn't contain text, apart from the nomenclature of the drawings and some notes on how to prepare mortar and distemper stone as *post scripta*.

2. Squinch vault

3. Ponc Descoll traced the trompes of the Royal Palace in Perpignan [1295-1309], then moved to Mallorca where he built the trompes of the Palau de la Almudaina [1309] and the trompes of the Trinidad Chapel in the Cathedral [c. 1330]. Gullierm Sagrera, a native of Felanitx, gained an important post as architect of St. Jean at Perpignan, then moved back to Mallorca to assume the duties of architect of the Cathedral [1422] and to project the Lonja and its marvels in stonecutting. Pere Compte, originally from Girona, from 1481 worked on the Palau de la Generalitat Valencian and probably on the trompe of the patio. In 1490 he started to work on the Seu of Tortosa. He was probably trained under Frances Baldomar [active in Valencia between 1425 and 1463], the author of emblematic stereotomic architectures.

4. For more information about the exchange of knowledge and stone masters see the studies of Joan Domenge i Mesquida and Mercedes Gomez-Ferrer.

5. The initial part of a trompe, a special piece of stone placed on the vertex of the cone to receive the blocks and avoid the very acute angles and easy breaking that would result if the stones were to meet at a single point.

6. Jousse's treatise has not been found in the known libraries of stonemasons of Barcelona but an anonymous manuscript recently found in Valencia has similarities with the characteristic method for cutting the stone for a groin vault described by Jousse. We could suppose that the content of Jousse's treatise was known in the *Levante Iberico*.

7. We can find the most notable example in the courtyard of the old Hospital de la Santa Creu from the 15th century in Barcelona (Fig. 2); another interesting example is in the Parish Church of Santa María in Caldes de Montbui.

8. The tool that the stone mason uses to transfer the angles previously calculated in the tracing to the stone.

9. Antonio Rovira y Rabassa 1897, vol. II, 701, reminds us of another example of trompe in the fortifications of Barcelona, now destroyed: "La trompa cónica en esbiage establecida en el interior de un muro en talud [...] Un caso notable de trompa de esta naturaleza es la que estaba dispuesta en uno de los muros de las fortificaciones de la ex ciudadela de Barcelona."

10. "Ejemplo notable de este caso lo ofrece' una trompa establecida en las ex-murallas de Barcelona [...] trompa de bastante vuelo y que aún recordamos, á pesar de los años transcurridos desde su demolición" (Rovira y Rabassa 1897, vol. II, 692).

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